1-2014

Girls Coming to Tech: A History of American Engineering Education for Women

Amy Bix
Iowa State University, abix@iastate.edu

CONTENTS

INTRODUCTION

Engineering education in the United States has a gendered history that until relatively recently prevented women from finding a comfortable place in the predominantly male technical world. Throughout the nineteenth century and most of the twentieth, American observers treated the professional study of technology as men's territory. For decades, women who studied or worked in engineering were popularly perceived as oddities at best and outcasts at worst because they defied traditional gender norms. By the 1950s, women still made up less than 1 percent of students in U.S. college and university engineering programs. Sixty years later, in academic year 2010–11, women earned 18.4 percent of engineering bachelor's degrees, 22.6 percent of master's degrees, and 21.8 percent of doctorates, and female faculty members held 13.8 percent of tenured or tenure-track positions in engineering departments.[1] Although those levels of female representation fell far short of demographic parity, by the twenty-first century, women's participation in American engineering programs had become accepted, even officially encouraged. Such a welcome should not be taken for granted. In historical terms, it represented a dramatic shift in the essence of engineering education, which was long presumed to be inherently, purely masculine.

This book examines the issues and tensions that were generated as female students sought to enter engineering programs in the United States, starting from the appearance of a few "engineeresses" at public land-grant schools and small private institutions in the late 1800s. The first women who pursued engineering were labeled as *others*, a small, threatening group of outsiders "invading" a man's world. In many important organizations, formal barriers maintained engineering as a male-only preserve. Up to World War II and beyond, some of the nation's foremost technical institutions refused to enroll female undergraduates. Many male students, faculty, and alumni at elite schools

openly criticized or ridiculed the idea of women engineers. Leading national engineering scholastic honor societies refused to grant full membership to women who matched or exceeded men's academic performance. Unwritten rules also discouraged women from attempting to begin an engineering education. The few young women who were admitted to the Massachusetts Institute of Technology before World War II struggled against a hostile intellectual and social environment. Those who resisted coeducation feared that girls could not fit "naturally" into technical programs, with their weight of masculine traditions.

At the most basic level, changing the gendered dimensions of technical studies required that all-male programs begin to grant access to female students and that coeducational colleges agree to expand beyond a grudging token enrollment of women in engineering. During World War II and throughout the 1960s, key institutions gave in, one at a time, under various legal, political, and social pressures. Advocates of coeducation insisted that given a fair chance, a sizable number of women could hold their own in engineering classes. They had to convince skeptics that admitting women would not undermine the quality of technical training and that enough women would be interested in engineering to make college recruitment worthwhile. The emergence of second-wave feminism and the broader social evolution of American gender roles during the second half of the twentieth century helped to break down legal and cultural barriers that had long limited women's employment and education.

Even after female students gained new opportunities to enroll in engineering, however, many were deterred, disheartened, or driven away by a cold or even antagonistic atmosphere. The debate over women's place in engineering served as a barometer of gender biases, displaying society's limits on what it accepted as masculine and feminine cognitive categories. Powerful cultural systems legitimated and facilitated "proper" choices for college majors for men versus women. The authority and tradition that had long made engineering a virtual male monopoly often made women feel like uninvited intruders in classrooms, laboratories, and residence halls. Marginalization, isolation, and various degrees of harassment made everyday campus life difficult for many (though by no means all) female engineering students. Sexual and intellectual tensions overshadowed and complicated their relationships and interactions with male classmates, other women, male professors and administrators, and even some family members and casual acquaintances who reacted with disbelief, laughter, or scorn to the phrase *woman engineer.*

Individual resources, luck, and personal support helped a growing number of women complete engineering degrees, often with pleasure and distinction, during the decades

following World War II. More than that, engaged female students, women professors and professionals, and male allies started vigorously promoting the campus and cultural dialogues that were necessary to battle discrimination against women in engineering. In the process, they raised thorny but profound issues about the gendered nature of childrearing and early education, the legal and cultural manifestations of second-wave feminism, the acceptability of women's aspirations, and the nature of engineering itself.

This book details the intellectual, institutional, and social revolution in gender dimensions of American engineering education from the late 1800s through most of the twentieth century. For focus, it centralizes gender over other vital demographic variables such as race and class. When female white engineers were scarce, female black engineers and those from other minority backgrounds were even rarer. Amy Slaton's pathbreaking analysis of the history of engineering education for African Americans in the United States after World War II examines detailed case studies of three key institutions.[2] Although her work shines a spotlight on race, gender remains mysterious, and the net effect regrettably pushes African American women to the sidelines. Other scholars will also need to track important questions of how women's postgraduation employment and professional identity in engineering developed from the nineteenth century through today. This analysis covers only the United States; in Europe and elsewhere, statistics for women's presence in engineering studies do not automatically parallel U.S. figures. Many countries, including Norway, France, Portugal, and Bulgaria, have witnessed a sharp rise in women's presence in engineering over recent decades. Although gender discrimination has by no means been entirely eliminated, the experiences of these women in non-American engineering studies have followed a distinctly different history.[3]

This work does not pretend to encapsulate the stories of all female engineering students in the country over more than ten decades. Instead, its chapters seek to capture the voices of numerous female engineering students and those who interacted with them within a certain set of historical contexts. Of these women, some felt thrilled and rewarded by the process of coping with a traditionally male field, while others became frustrated or infuriated by the struggle. Readers who are engineers themselves or witnessed the history of engineering coeducation may find some stories that resonate; others will inevitably have a different perspective. Each woman entering engineering studies brought a unique psychological and personal background to her experience; on campus and off, each interacted with different individuals in different circumstances that together colored elements of her overall life as a female engineering student as good, bad, or just different.

This book is for the generations of students, faculty, administrators, and professionals who lived through the shifting gendered climate in engineering education and who observed or helped shape developments at MIT, Georgia Tech, Caltech, Iowa State, RPI, and other schools around the country. In talking with women who currently are majoring in engineering at different institutions, I have met many whose satisfying experiences make them almost unable to comprehend the depths of past discrimination, as well as others who remain upset by the ongoing manifestations of sexism that they encounter in college settings. This historical perspective may benefit both groups, helping the first set appreciate just how much has changed over the decades for women in engineering studies, while giving the second group hope that conditions can and will keep improving.

ILLUMINATING THE HISTORY OF GENDER IN ENGINEERING EDUCATION

Margaret Rossiter has written that before 1940, "women scientists were . . . caught between two almost mutually exclusive stereotypes: as scientists they were atypical women; as women they were unusual scientists."[4] Such a statement applies many times over to the condition of female engineering students in the United States over a far longer period of time. Indeed, some scholars would argue that even today, female engineers are still popularly perceived as more atypical than female scientists. Most ordinary citizens have heard of Marie Curie, at least, but might be hard-pressed to name a single woman engineer. Women's engineering ambitions were of a more deeply transgressive nature because technical knowledge—with its ties to industry, heavy manual labor, and the military—was a far more masculine domain than science was. As would-be engineers, women faced wider resistance, both formal exclusion and casual discrimination, especially at the most elite levels of education. Throughout most of the twentieth century, they faced distinct challenges on the grounds that as women, they were not "proper" engineers and as engineers, they were not "proper" women.

Historically, women in engineering programs stood out due to their rarity, even more than in science or medicine. In seventeenth-, eighteenth-, and early nineteenth-century Europe, upper- and upper-middle-class families often allowed and even encouraged girls and adult women to pursue certain scientific interests, providing they did not take their scholarship so seriously as to endanger their prospects for marriage and motherhood. Progressive educators such as Jan Comenius, Anna Maria von Schurmann, Bathusua Makin, and Mary Astell argued that female minds were not inherently inferior to those of males and campaigned for reforming girls' education to include more

challenging and significant subjects. Advocates praised scientific inquiry as a valuable method for cultivating virtues such as patience, perceptive observation, and a reverence for God's creation. Society considered botany to be an acceptable extension for a feminine love of nature; the study of flowers offered artistic women scope for illustration and painting. *The Ladies' Diary* magazine offered readers the chance to solve algebra problems and speculate about scientific puzzles. In 1686, Bernard de Fontenelle wrote an astronomy book (translated into English by famous female playwright Aphra Behn) that was structured as a fictional flirtation between a gallant young scientist and his noble female pupil. Their conversational exchange was designed to interest and instruct female readers, in particular, about the Copernican universe, mechanistic physics, and even speculations about extraterrestrial life. Also adopting dialogue form, in 1805, Jane Marcet published the book *Conversations on Chemistry, Intended More Especially for the Female Sex*. In the early 1800s, Margaret Bryan opened an elite London girls' school that taught science and mathematics.[5]

During the colonial era of American life, "dame schools" offered young girls elementary literacy, while boarding schools taught wealthier girls to raise their matrimonial prospects by becoming proficient in attractive arts, including embroidery, drawing and painting, music, dancing, and French. But by the Revolutionary and early national periods, influential figures such as Judith Sargent Murray, Abigail Adams, and Benjamin Rush argued for extending young women's education beyond such "ornamental" skills as a political and social asset to the country. Representing what historian Linda Kerber has described as the philosophy of "Republican motherhood," Rush linked future national liberty to the contributions of patriotic, cultivated women who would instill in sons the moral and practical lessons to turn them into contributing citizens and strong leaders and would train daughters to become the next generation of virtuous wives and mothers. In his 1787 speech to the Young Ladies' Academy of Philadelphia, Rush argued that young women should master good grammar, handwriting, bookkeeping, and essential mathematics so that they could maintain household budgets and help a husband with business. To help a girl mature into "an agreeable companion for a sensible man," Rush also regarded some training in religion, geography, and history as valuable, alongside "a general acquaintance with the first principles of astronomy and natural philosophy, particularly . . . to prevent superstition." Murray and other advocates emphasized that young women deserved the chance to gain self-confidence and the skills that would help them to sustain a well-run home and, if left a widow, to support themselves and their children.[6]

Critics warned that educating young ladies beyond the mere basics would render them unmarriageable, destroy their natural femininity, tempt them to neglect domestic

duties, and undermine man's God-given position as a superior creature. Still, by the 1790s, female academies were flourishing in New England, as scholars such as Nancy Cott and Mary Beth Norton have documented. In cities and smaller towns, these academies spread and regularized young women's training in composition, arithmetic, history, and geography. Educators generally thought it inappropriate for women to study Greek and Latin. Although the vast majority of families could not afford to grant their sons the luxury of pursuing higher education, in the eighteenth century, Harvard College and the College of William and Mary trained ministers, lawyers, and men of leisure, occupations that were firmly barred to females.[7]

By the 1820s and 1830s, national expansion opened up one new rationale for "female improvement." Increasing numbers of white children attended school, at least part-time, not just in urban areas but in Midwestern frontier territory, and local officials realized that it made sense to replace male instructors with young women, who eagerly worked at a lower pay. Given assumptions that women had a natural skill and interest in childrearing, it did not radically threaten established order to have them teach boys and girls, especially if those teachers resigned after a few years to get married. Arguing that better-prepared female schoolteachers would handle classrooms more adeptly, entrepreneurial advocates founded ambitious new institutions for women's education—Emma Willard's Troy Female Academy in Troy, New York (1821), Catharine Beecher's Hartford Female Academy in Hartford, Connecticut (1823), and Mary Lyon's Mount Holyoke Seminary in South Hadley, Massachusetts (1837). All drew increasing numbers of middle-class daughters. According to Kathryn Kish Sklar, Beecher in particular promoted teaching as a desirable uplift for young ladies that gave them a worthy purpose in life and a chance to contribute to community life without contesting man's public role. Such principles reflected the rhetoric of advice books, popular women's magazines, and the writings of public figures. That prescriptive literature equated feminine nature with an idealized selflessness, emotional nurturing, and a pious purity that molded children's characters and influenced the world for good. Teaching offered women a morally irreproachable opportunity to support themselves without the hard physical stress of farm work or factory jobs such as those in the Lowell, Massachusetts, textile mills.[8]

Although relatively well-off white women gained opportunities to attend all-female institutions during the early nineteenth century, coeducation at the higher levels of study appeared far more slowly. Oberlin College, founded in 1833, soon admitted female students and African Americans alongside white men, living up to the institution's progressive outlook on learning as a vehicle for social justice in causes such as Christian missionary outreach and the abolition of slavery. State universities such as those

in Wisconsin and Michigan moved toward coeducation over the next few decades, a trend that gained momentum in 1862, when Congress passed the Morrill Act creating the mechanism to support public land-grant education. The legislation did not require land-grant institutions to allow in female students; those in southern and some eastern states often denied or delayed women's access, while other schools, such as Cornell and Nebraska, became coed relatively early.

Trustees at Iowa State College, which admitted women from its opening in 1869, declared, "If young men are to be educated to fit them for successful, intelligent & practical farmers & mechanics, is it not as essential that young women should be educated in a manner that will qualify them to properly understand and discharge their duties as wives of farmers & mechanics? We must teach the girls through our Agricultural College to acquire by practice a thorough knowledge of the art of conducting a well-regulated household, practiced in our Farm House, Boarding Hall, garden, dairy & kitchen." First president Adonijah Welch spoke about giving female students "increased facilities for scientific instruction," with a "prominent" place for "the study of domestic economy." His wife, Mary Welch, helped create Iowa State's first official class in scientific homemaking in the 1870s, called "Chemistry as Applied to Domestic Economy." But that study of household matters represented only one course in the "ladies' course of study" in 1871, which otherwise required female students to take a year's worth of inorganic and organic chemistry or qualitative analysis, botany and physics, psychology, comparative anatomy and physiology, geology, meteorology, history, and the "study of Shakespeare," with options in Latin, French, literature, music, and drawing.[9]

As Andrea Radke-Moss has documented, coeducation did not automatically imply integration. Nebraska physically separated women's and men's seating in classrooms and other college functions in the 1870s, and authorities imposed rules to minimize unnecessary conversations and interactions between the sexes. Nevertheless, some nineteenth-century advocates of coeducation hoped that the female presence could exert a civilizing influence, calming the unruliness, drinking, and even violence among male students. As is discussed below, promoters used similar arguments to press for admitting women to Caltech's engineering and science environment in the 1960s.[10]

Across the United States, by 1870, women comprised about 21 percent of total undergraduate enrollment, rising to 32 percent in 1880, just under 40 percent in 1910, and 47 percent by 1920. Their growing presence sparked a backlash, as critics warned that female dominance would destroy the strength of American higher education.[11] Amid these gender tensions, men on some campuses found many ways to marginalize or even harass their female counterparts. As Rosalind Rosenberg has discussed, male students at

Wesleyan University once punished classmates who were seen conversing with female students and rendered women invisible by excluding them from the yearbook. Some professors remained skeptical about women's presence and sometimes pretended that they did not exist, addressing them as "Mister" or using last names.[12]

In 1873, Edward Clarke, a Boston physician who taught at Harvard Medical School, wrote *Sex in Education, or, A Fair Chance for the Girls*. Although Clarke did not flatly reject the idea of women pursuing intellectual work, he warned that for physical reasons, they should not follow an educational course identical to and as demanding as men's. Medical theory of the day often conceived of the body in terms of specific amounts of resources, and Clarke claimed that if women strained their biological systems by studying too long, especially during each month's menstrual period, they would divert too much energy to their brain and deprive their reproductive organs of essential support. He reported that he knew a number of cases of female students who pushed themselves too hard and collapsed from exhaustion and physical distress before graduating, or who finished college and found themselves unable to bear children and be proper wives to their husbands, or who died after destroying their brains. Clarke's book went through numerous reprintings, and many American readers took his concerns seriously, especially when the eugenics movement sounded an alarm that white women were not bearing enough children to counterbalance the immigration and reproduction of "unfit" minorities and ethnic groups, who supposedly were prone to physical weakness, mental instability, criminality, and socially expensive vices. To fight criticism that higher education ruined female health, women's colleges required students to study anatomy and take regular gym classes. Advocates encouraged young women to pursue ladylike extracurricular sports such as golf, skating, calisthenics, swimming, and basketball (under special rules that limited speed and contact) that were meant to foster exercise without developing the muscles or aggressive competitiveness that properly belonged only to men. Women's colleges and the Association of Collegiate Alumnae (which later became the American Association of University Women, still in existence) collected data to document that female students did not suffer from serious illness and proved perfectly capable of bearing and raising healthy children.[13]

Despite the ongoing levels of discomfort with higher education for American women, female students could, with varying levels of difficulty, find entry points to get a foothold in science, especially after the mid-1800s. Following Mary Lyon's path in establishing Mount Holyoke, the rest of the Seven Sisters (and some other women's colleges) kept raising academic standards for female students, encouraging them to pursue and succeed in science disciplines as well as in the humanities, arts, and social sciences.

Vassar invested resources in building its own medical lecture room and geology collections. In 1865, Vassar hired internationally famous researcher Maria Mitchell to head its astronomical observatory. Mitchell became the first woman member elected to the American Academy of Arts and Sciences and at Vassar trained a new generation of respected female astronomers. Vassar required all students to take at least one semester of chemistry, plus botany, zoology, geology, and physiology. Charismatic chemistry professor Charles Farrar influenced numerous students, including Ellen Swallow, who went on to become the first woman admitted to MIT and, as a chemistry instructor there, helped open its doors to other female students. At all-female Wellesley College, Sarah Frances Whiting taught astronomy, physics, and meteorology, introducing students to spectroscopy, X-ray photography, and other novel scientific advances. In 1878, Wellesley encouraged Whiting to follow MIT's model and establish what became (after MIT) the country's second undergraduate experimental lab dedicated to physics. Barnard College allowed women who were based in New York City to study chemistry and biology, while Bryn Mawr advanced the principle of opening graduate-level education to women. Meanwhile, by the early twentieth-century at coeducational state land-grant colleges, home economics programs required women to study physics, physiological and nutritional chemistry, food analysis, research statistics, and scientific writing.[14]

Margaret Rossiter has described an "infiltration" process before 1940 that allowed individual women, who could find sympathetic male faculty as sponsors, to work their way into doctoral science programs. Those who earned degrees immediately confronted an entrenched discrimination against female scientists that presented numerous obstacles in the educational system, in the scientific profession itself, and in the general culture. As Rossiter has thoroughly detailed, patterns show that many graduates were channeled into "women's work"—research-assistant jobs with relatively low pay, low recognition, and little opportunity for advancement. Yet as illustrators of scientific books, museum catalogers or curatorial associates, lab technicians, and number-crunching "computers" in astronomical observatories, women at least maintained a relatively permanent presence in science. Especially in biology and specialized subfields of chemistry, early twentieth-century women made incremental inroads into the scientific establishment, although many still had to fight to win grudging or belated credit for their talent.[15]

Similarly, although many American medical schools and teaching hospitals limited female admission well into the twentieth century, other routes almost always offered some women access to practice medicine. Since ancient times, women throughout the Western world often served as informal healers and midwives within the family or community, drawing on shared knowledge of homemade herbal remedies and folk cures.

Women continued to fill those roles in early America and later frontier life at a time when medical licensing laws were lax and many male doctors opened practices without having completed much formal training. Popular "alternative" treatment philosophies, such as homeopathy and hydropathy, cultivated a clientele of female patients and often welcomed female practitioners especially to treat other women.[16]

As new mainstream medical schools arose and spread in the United States during the nineteenth century, a few persistent women managed to claim places, starting with Elizabeth Blackwell, who earned a degree from Geneva Medical College in 1849. But because most American medical schools excluded women and hospitals routinely denied female physicians access to internships, Blackwell and her few female medical colleagues created their own female-run medical colleges and female-oriented hospitals in Philadelphia, New York, Boston, Chicago, and other cities. Those institutions were devoted to training the next generation of women physicians and supporting their instruction in clinical practice.[17]

Gatekeepers sought to discourage women, warning that medical studies would be too taxing for their weak nature and that topics such as reproductive medicine and venereal disease were too unseemly for ladies' ears. But even as critics denounced it as inappropriate for female physicians to handle bloody injuries and the bodies of strange men, more women began serving as nurses. Newspaper and magazine writers romanticized the "angels" who combined feminine ideals of sentimental compassion and gentle caretaking. Their portrayals depicted nursing as a higher calling of selfless service. Especially during and after the Civil War, female nurses became an indispensable mainstay of battlefield medical tents, hospitals, and other care facilities. Observers considered nursing a "proper" station for women, which relegated them to a professionally and socially subordinate station behind male doctors. Nevertheless, during the late 1800s, women who wanted to become physicians gradually gained new access to medical training at public institutions in states such as Michigan. In the 1880s, Blackwell and her allies successfully pressured the Johns Hopkins Medical School to become coeducational. Hopkins subsequently trained a significant number of women, including Florence Sabin, whom Hopkins hired as its first female faculty member. According to some historians' estimates, women comprised roughly 18 percent of the doctors who practiced in Boston in around 1900.[18]

Virtually none of that record for women in science and medicine held true for women in engineering. Women had long been inventors and innovators, even if they did not apply for legal patent protection. Across cultures and through generations of farming, food preparation, and home making, women for centuries had acquired and

refined a wide range of technical skills and experience. Women produced textiles and embroidery, both in the household and in early industrial employment, and women in seventeenth-century France found employment as laborers who built canals.[19] But the modern Western concept of engineering grew out of the Renaissance, when men such as Leonardo da Vinci and Francesco di Giorgio Martini allied art and architecture to mechanics, specializing in the design of siege engines, cannon-resistant fortifications, waterwheels, and geared machinery. France's Ecole Polytechnique systematized the foundations of formal instruction in military and civil engineering. In the United States, West Point was founded in 1802 and hired key professors from France, endorsing training that was rooted in Newtonian mechanics, descriptive geometry, and other higher mathematics. Graduates worked for the U.S. Army Corps of Engineers or with private companies and applied that knowledge to lay out new roads, plan canals and bridges, and improve harbors and other infrastructure.[20]

Opportunities for men to pursue formal studies in technical subjects slowly expanded. In upstate New York, the school later known as Rensselaer Polytechnic Institute began offering civil engineering degrees in 1835. Harvard set up the Lawrence Scientific School in 1847, at about the same time that the Sheffield Scientific School opened in connection with Yale. Instruction in mathematics and theoretical science shaded into work in practical chemistry and applied science. As Terry Reynolds has shown, numerous other antebellum institutions, especially in the South and frontier West, incorporated a partial technical instruction into more broadly defined curricula. Congress passed the 1862 Morrill Act to provide federal assistance for the teaching of topics that were "related to agriculture and the mechanic arts." Advocates promoted the ideal of a democratically accessible education that offered practical value. It aimed to set young people on rewarding paths in life while advancing knowledge of farming and manufacture for state and national economic benefit. By 1872, the United States had about seventy departments or schools that taught engineering. Although some degree programs increasingly stressed research and theoretical principles, other programs maintained extensive shop-work requirements to ensure that graduates would fit into industry and not appear to be abstract bookworms who could not tell one tool from another.[21]

Even as American colleges and universities began producing more engineering graduates, many more men still entered the field without degrees. For them, the drive to build the Erie Canal, survey railroad lines, design water and sewer systems for expanding cities, and advance steam-powered business all provided immediate technical experience. Such hands-on training cultivated experts in practical problem solving who mastered the basics of mapping, math, and mechanization on the job. A number of

nineteenth-century mechanical engineers, for example, began as apprentices in small machine shops or railroad yards and then worked their way up to machinists. Through repairing locomotives and servicing equipment, participants acquired sophisticated experience with engines. As historian Monte Calvert has suggested, leaders of this "shop culture" indoctrinated young men into the traditions of work and an entrepreneurial orientation.[22]

As the twentieth-century began, an increasingly standardized "school culture" came to dominate engineering, fostering the spread of programs that offered advanced degrees. Graduates often secured jobs with major corporations such as General Electric, DuPont, and AT&T rather than with small businesses. The engineering "organization man," to use a later nickname, gained the opportunity to enter management, reflecting the development of large-scale technological systems in the big-business world of mechanical, electrical, and chemical industries. Training became specialized into a rising number of subdisciplines, each with separate professional organizations, publications, and requirements for membership.[23]

For women in the United States in the 1800s and early 1900s, the U.S. Army Corps of Engineers, the Erie Canal, railroad shops, mines, and corporate engineering all remained remote. There was no pure engineering equivalent to domestic science or homeopathy, an alternative philosophy or direction of practice outside the professional mainstream that proved comparatively open to women. In contrast to the world of popular science, publishers did not turn out engineering books or magazines that were devoted to translating the latest discoveries for a female audience. Educational reformers did not call for engineering classes for women, and the popularity of science as a ladylike pursuit in upper-class society did not extend to applied technology. The all-female medical schools and the science curricula offered by women's colleges had no parallel in engineering; there were no separate engineering programs set up by and for female engineers that hired other women as instructors. Even secondary paths to technical employment were thoroughly blocked. In medicine, nursing offered an accessible alternative for some women who could not afford or arrange for a doctor's training. Women with science degrees could hold associate researcher positions or find employment at women's colleges in teaching female students. As discouraging as those low-appreciation paths in medicine and science might be, engineering lacked even those fallback options for giving women a place on the sidelines.

Instead, male engineers deliberately cultivated a macho image for their field, as scholars Carroll Pursell, Sally Hacker, Cynthia Cockburn, and others have detailed.[24] Marketers encouraged boys to play with Erector sets and model trains and marketed toy kitchens

and dolls for girls. Few women were welcome in factories or machine shops. Engineering schools portrayed their field's all-male nature as inherently obvious and necessary. In her work *Making Technology Masculine*, historian Ruth Oldenziel paints a clear picture of a "male romance with technology" and discusses the factors that made engineering historically masculine. Through self-promoting autobiographies, professional rhetoric, and fraternal language, middle-class white men of the late 1800s and early 1900s claimed for themselves an engineering identity. Popular writers celebrated the vigorous heroism of engineers who tamed nature through ingenuity, courage, and sheer effort.[25]

All this made it unusually difficult for women to break into engineering, and the story of how they did so tells us as much about engineering itself as about the women. As Karen Tonso has written, "Engineering education, as one facet of engineering culture, is not simply training in a prescribed set of appropriate, academic courses, but is enculturation into a well-established system of practices, meanings, and beliefs . . . 'passed down' from mature practitioners to novices . . . in activities through which engineering traditions are propagated. Thus, as engineering students progress through their undergraduate engineering education, among the things they learn is what it means to be an engineer."[26] Although historians, sociologists, and other observers have produced many books about female scientists and healers and about gender issues in the practice of science and medicine, astonishingly little has been documented about the history of women and engineering. In 2001, Betty Reynolds and Jill Tietjen published *Setting the Record Straight: The History and Evolution of Women's Professional Achievement in Engineering*, a short survey of the story from ancient times (with Hypatia and Miriam the alchemist) to 2000, with an emphasis on key female figures. Other writers have offered biographical and autobiographical perspectives on individual female engineers. The lion's share of attention has gone to Lillian Gilbreth, well-known even among nonhistorians for the popular movies and stage plays that were loosely based on her children's accounts of their unusual family life—*Cheaper by the Dozen* and *Belles on Their Toes*. Jane Lancaster has written a valuable biography of Gilbreth titled *Making Time: Lillian Moller Gilbreth—A Life beyond "Cheaper by the Dozen,"* and Laurel Graham has written the more focused work *Managing on Her Own: Dr. Lillian Gilbreth and Women's Work in the Interwar Era.* But although Gilbreth, as "the first lady of engineering," was unquestionably influential in shaping the future for other female engineers, her story is unique in so many ways that it does not begin to address the broader history of women's entrance to the field.[27] The historical field has reached a point that calls for a substantive narrative shift, extrapolating beyond individual accounts and anecdotes to analyze institutions, aggregate trends, and systemic concepts such as the evolution of engineering-school gendered climate.

Beyond the biographical approach and isolated studies such as the work of Oldenziel, Hacker, and Reynolds and Tietjen, literature on the history of gender and engineering in the United States remains sparse. The field widens, though only somewhat, by expanding the geographic scope. Most notably, *Crossing Boundaries, Building Bridges* compares the history of women, men, and engineering across Europe and elsewhere. Editors Annie Canel, Ruth Oldenziel, and Karin Zachmann discuss how "the timetables by which women entered engineering deviated so dramatically" depending on social context and national and international political events. For example, feminist and reform sentiment in Russia inspired the creation of a female school for engineering and applied science school in 1905, the St. Petersburg Polytechnic Institute, and France established the Ecole Polytechnique Feminine in 1925.[28]

Other than such special monographs, standard works on the history of engineering often take for granted (and thereby reinforce) the sense of technical work as a disciplinary presence defined by masculinity. Studies of the history of specific American colleges and universities, such as Georgia Tech and MIT, concentrate on the development of engineering at a particular institution. However, most of these books either ignore gender issues in the history of engineering programs or acknowledge in passing the presence of a few female students and staff.[29]

Recent years have brought an extensive and varied literature on the conditions that face women in American engineering today, including works sponsored by organizations such as the National Academy of Science, the National Academy of Engineering, and the Society of Women Engineers. Books, articles, working papers, and other publications in this genre typically explore various psychological, social, political, economic, and intellectual barriers that contribute to female underrepresentation in engineering, studying strategies to overcome such factors and support greater educational and workplace inclusivity.[30] These valuable materials approach current issues in engineering education and practice from the perspectives of sociology, gender studies, and education studies, but they generally do not analyze the historical background that set the stage for the ongoing tensions that face women in engineering. A parallel set of works assesses the broader situation for women in United States STEM fields (science, technology, engineering, and mathematics), including topics such as curriculum reform and career-pattern complications, as seen in the writings of Sue Rosser, Mary Frank Fox, and many others.[31] Feminist historians and philosophers, such as Evelyn Fox Keller, Sandra Harding, Londa Schiebinger, and others, have inquired whether it is possible to create a gender-free science and, if so, what would shape its characteristics.[32] Although discussions focused on science can offer substantial insights into modern questions of gender

equity in engineering, the contrast between women's relative levels of representation in engineering and biology is substantial. Such differences are no accident. In many ways, they reflect separate historical paths in the development of scientific versus engineering education for women and also in the different professional climates and gendered culture.

GENDER STUDIES AND HISTORICAL CONTEXT FOR WOMEN PURSUING "MEN'S WORK"

This account of women's entry into engineering studies reflects a broader historical context and the interplay of gendered dynamics within the changing patterns of American life. Just as in other social institutions (such as the workplace, religious groups, media, the political system, and the family), individual women's experiences in higher education were mediated by the stereotypes, expectations, and realities of gender identity. The men who were the central actors at engineering schools—the students, teachers, and administrators—carried normative power to define, assert, and police standards. Their dominant values, dictating what men and women should want and could do, matched and justified the institutional and social barriers that separated women from technical expertise. Gendered consciousness and control shaped discussions of engineering coeducation. According to conventional wisdom, male and female identities provided an elementary filter that defined the appropriateness of whether a particular student should or could enter engineering. Engineering culture contained embedded stereotypes about gender, infusing assumptions about technical knowledge and masculinity into the cognitive machinery of successive generations. Even when male and female classmates sat in the same lecture halls, completed identical homework, and took exams together, gender inescapably penetrated that shared surface experience sooner or later, with blatant or subtle ramifications. Individual choices, actions, and interactions never came in a vacuum; they often, though not inevitably, reflected underlying gendered practices. Questioning masculine and feminine norms, either explicitly or implicitly, required effort and bravery.

Language matters. For decades, the commonly used term *coeds* differentiated women from the default *college student*, especially since the awkward antonym *eds* for male students never really caught on. The nicknames Joe College and Betty Coed encoded men's position at the center of campus life and women's role as an asymmetric accompaniment. Female engineering students always remained a subset of the full population of campus women. They shared many college experiences with women in other majors, including sorority life, music groups, the dress code, and other rules governing

women's behavior. Yet for women studying engineering, many personal aspects of college life, from dating to decisions about how to present themselves in everyday appearance, acquired an extra layer of complexity. Their identity as female engineering majors uniquely colored perceptions about them, both as individuals and as a group. Like their dorm-mates pursuing literature, librarianship, education, arts, home-economics, psychology, and social work, female engineering students were perceived in terms of broader cultural impressions of "college women" and in turn responded to such expectations. During World War II, patriotic messages pushed young women to contribute to national defense. After the war ended, a supposed return to normalcy fed a trend toward early marriage and conventional division of labor between the male breadwinner and female homemaker. In practice, class, race, and other factors prevented large numbers of women from conforming to this conventional "Leave It to Beaver" model even at the height of its cultural dominance, while other postwar women appreciated the sense of accomplishment and financial independence that they gained from working outside the home. Yet the vast majority of college-trained women continued to enter conventionally gendered (and often relatively low-paid) fields, including teaching, bookkeeping, nursing, retail, libraries, and social agencies. Even during the decades when total female participation in the labor force rose, women in engineering remained starkly separate from their far more numerous counterparts who chose the paths of less resistance and so occupied a different space within the "college woman" context.[33]

A chain of gender stereotypes left female engineering students of the postwar decades boxed into one of two disagreeable roles. The standard premise was that a normal woman would prefer to study almost any field other than engineering. Starting from this premise, many classmates, teachers, and outside observers concluded that the few college women who defied such norms could not be serious about their work and had entered engineering only to catch a husband—in which case, faculty and male classmates did not need to respect the women's intellectual ambitions. The second corollary suggested that those women who were *too* serious about their work must therefore be inherently unfeminine—in which case, college men felt free to slander them as unattractive. Whenever a female engineering student dropped out of college or switched majors (especially when frustrated by an unfriendly reception), observers might interpret her individual "failure" as confirming the wider gender truth that engineering belonged to men. The assumption that women naturally tied their emotions and values more to family than to occupation (and the reverse for men) fed suspicions that top-quality engineering training would be wasted on women. When female engineering students married before or soon after graduation, they seemed to validate the notion that women

were more dedicated to intimate relationships and babies than to "real" work. Those female engineering students who did not marry at the culturally standard age seemed to verify doubts about whether they were "real" women. Such gendered assumptions spilled over into decades of workplace discrimination when female engineering students encountered some potential employers who refused to take them seriously or questioned whether women could commit themselves to a job as intensively as a man supposedly did for any length of time.

In practice, over the decades, many individual women who entered engineering studies did manage to escape this rhetorical trap. Given the obstacles that they faced, an impressive number succeeded in securing decent employment while getting married (often to men they met as engineering classmates or coworkers), raising families, or otherwise enjoying fulfilling personal lives. But it was no accident that female engineering students repeatedly asked their mentors about the "secrets" to combining employment with child bearing and child rearing and about the best strategies for reentering the labor force after temporarily stepping out of it. Male engineering students rarely, if ever, explicitly confronted or agonized over questions about family and career balance. Prevailing cultural standards dictated that women who held employment outside the home should continue to assume the bulk of responsibility for domestic chores and child care—the "second shift" of shopping, laundry, bedtime routines, and more.[34] Although society might tolerate and sometimes celebrate eccentrics, women (and men) generally earned higher approval and rewards by following gendered models, and women who opted to follow "men's work" in fields such as engineering defied expectations. To offset such nontraditional choices, some women might deflect implied or explicit criticism by paying special attention to performing femininity in their personal lives. In other cases, journalists and other observers might impose visions of idealized gender on nontraditional women, assessing and emphasizing the cooking or sewing skills, family devotion, appearance, or fashion choices of female engineers. Consciously or unconsciously, individual women in engineering studies had to decide how to position themselves—as "one of the guys" who sidelined her femininity during work hours, as an engineer who took pride in combining a displayed femininity with technical competence, or some alternative tactic. But inevitably, some responses to female engineering students lay outside their control. Parents, friends, classmates, teachers, potential employers, journalists, and the culture in general all had certain visions of "what women did," and engineering was not one of them.

In the face of such challenges, female engineers of the postwar era formed organizations such as the Society of Women Engineers to give each other mutual support and

to provide career counseling and mentoring, financial assistance, and psychological and social reinforcement for the next generation. The second-wave feminist movement of the 1960s and 1970s offered a broader basis for institutional change and women's individual empowerment. Activists, especially with the National Organization for Women, pushed to ensure that the Equal Employment Opportunity Commission actually enforced provisions of the 1964 Civil Rights Act that made it illegal to discriminate by sex when hiring or firing or in actual conditions of employment. Further legislation, policies, affirmative-action rulings, and numerous court battles followed, all seeking to clarify procedures for resolving complaints of unequal pay, hostile work environments, and sexual harassment. Beginning in the 1970s, discussions about workplace discrimination often grew heated, yet the balance of change clearly swung toward helping women close the gap in professional, economic, and social opportunities. Similarly, political and cultural pressure motivated many Americans to work toward resolving problems with women's access to equal educational conditions. Title IX, part of the Education Amendments Act of 1972, mandated that no federally supported educational activities could engage in discrimination on the basis of sex. Subsequent legislation, such as the Women's Educational Equity Act of 1974, expanded discussion of female students' well-being from primary schools through graduate training. Organizations such as the American Association for University Women lobbied to maintain this focus on equity. Its 1992 assessment, *How Schools Shortchange Girls,* warned about the cumulative effects of even seemingly small disparities, such as teachers who directed more attention to boys.[35]

Feminist consciousness raising, popular discussion, and academic studies deepened awareness of the complexities that lay behind gendered choices of university majors and professions. Increasing numbers of women and men alike explored the implications of a culture in which, long before women arrived at college, many social and psychological influences had already delivered the message that engineering was most appropriate for males. Interactions with parents, teachers, friends, and classmates conditioned norms that often linked masculinity to mathematics, hard sciences, and hands-on technical experience.[36] By deliberately or unconsciously treating young girls as less interested and less able than boys in science, math, and mechanical and building work, adults reinforced such presumptions both in individual children and as a broad generalization. Social learning separated carpentry sets, radio kits, model trains, and other boys' playthings from girls' dolls, sewing kits, and toy kitchens. Psychologists and sociologists documented how adolescent young men and women tended to become absorbed in adopting gender frameworks and defining personalized expression, a pattern that

coincided with crucial years of gatekeeping in secondary schools. Teenage girls who were subtly discouraged or openly counseled against enrolling in college-track mathematics were left at a disadvantage for considering engineering as a future option. Just as the feminist movement of the 1970s sought to break the barriers that deterred many young women from joining sports teams or male-only clubs, advocates mobilized to promote engineering as a visible, viable option for young women to consider before they reached higher education. Through outreach efforts, targeted workshops, elementary schools, Girl Scout programs, and more, female engineers presented themselves as models and as mentors who were eager to foster girls' curiosity about technology and awareness of career options.

CASE STUDIES WITH MEANING FOR ENGINEERING COEDUCATION

To raise the curtain, chapter 1 of this book details the handful of individual women who, as "rare invaders," breached the boundaries of masculine engineering education and work in the late 1800s and early 1900s. World War II proved a crucial transition, as chapters 2 and 3 document. National emergency led the federal government, schools, and industry to undertake coordinated efforts urging women to serve their country by entering engineering. The unusual pressures of wartime justified stretching gender boundaries, at least temporarily. Case studies detail the intense interest in women's technical potential and the complex path toward engineering coeducation in the United States during this crucial transition period. Manpower shortages led major American companies, including General Electric and Grumman Aircraft, to recruit and train women as engineering aides, channeling them directly into defense work. Although training programs for women were designed as temporary war expedients, they helped break down both formal and informal barriers to women's participation in the campus engineering culture. Most of those who participated in special wartime programs did not ultimately make full-time postwar careers in technical fields, but their numbers reflected positively on the growing number of women who were studying engineering for regular degrees during World War II. A critical mass made life easier, and high numbers helped validate the notion that women could handle technical subjects. World War II brought a number of "firsts" for women in engineering, including an increase in the number of women who were initiated into student honor societies (at least those that allowed female membership). At individual institutions, the difference was apparent; wartime permanently pushed open the doors of a few engineering programs to women, most notably, Rensselaer Polytechnic Institute. In 1949, across the entire

country, there were 763 female students enrolled in engineering; by 1957, that total had more than doubled to peak at 1,783. True, given that the number of male engineering students also soared, female students remained less than 1 percent of total enrollment. But their numbers proved sufficient to draw attention, especially in the broader context of gender-related changes in the workplace, higher education, and national society.

Chapters 4 through 6 here offer detailed case studies of the post–World War II debate over women's place in engineering at three significant institutions—the Georgia Institute of Technology, the California Institute of Technology, and the Massachusetts Institute of Technology. Covering the history of coeducation at every U.S. engineering program is beyond the scope of this book, but this suggestive sampling serves to highlight trends of change.

The in-depth case study of Georgia Tech offers an excellent perspective on the postwar period's heated debate over coeducation, since the institution's culture, customs, and community so closely connected engineering to masculinity. The college humor magazine ran entire issues that poked fun at the notion of female engineers. Nevertheless, the issue of coeducation appeared, with rumors in 1948 that women's organizations in Atlanta were preparing a court test case, a well-qualified young woman whose sex excluded her from any access to public engineering education in her native state. Georgia Tech's president advocated for gendered fairness, and facing that pressure, the Georgia Board of Regents in 1952 passed a measure (over much internal resistance) admitting women to Georgia Tech under limited circumstances. The first female students to appear on campus caused a sensation, and newspapers ran photographs showing women trying on Tech's traditional freshman "rat caps." These early generations of female students walked a tightrope politically, tactfully denying that women's presence would force any real change in the male-centered culture of their engineering school.

Caltech offers a valuable contrasting case study. As a private school, Caltech did not face the same threat of lawsuits over coeducation as had emerged in Georgia. Instead, in the mid-1960s, Caltech experienced internal pressure to begin admitting undergraduate women. Male undergrads had become restless, complaining that "Millikan's monastery" was an unhealthy social and intellectual anachronism that graduated brilliant scientists and engineers who were social idiots, unable even to talk to real women. In a 1967 survey, 79 percent of undergrads said they wanted Caltech to admit women. They promised administrators that a civilizing female presence would improve men's academic performance and even suggested that if Caltech relieved campus boredom by admitting women, male students would be less likely to indulge in marijuana. Some professors remained dubious about making Caltech coeducational, but administrators faced disturbing evidence that

good high school men were rejecting Caltech in favor of coed Stanford or Berkeley. In 1968, Caltech trustees voted to admit female undergraduates. Although school leaders spoke about fairness in giving women access to an excellent school, the change was not inspired by a passionate dedication to women's rights. Those leading Caltech did not believe that large numbers of young women would be interested in or qualified to study high-powered engineering. At least initially, Caltech's primary motivation for accepting women was to appease and retain its male students by providing them with girlfriends and social "normality." Picking up on that mentality, many of Caltech's first female students had to fight to be taken seriously as students, fend off unwanted sexual approaches, and struggle to develop their own identity as women engineers.

The final focus, MIT, also offers rich grounds for comparison. Unlike Caltech or Georgia Tech, MIT had been coeducational since the 1870s but treated women's presence as a minor afterthought. Before the 1940s, MIT never had more than sixty-five female students at any time out of a total student population of just under five thousand. Some faculty and administrators resented giving any seats at MIT to women, assuming that they would either fail to complete the program or squander their degrees by marrying and leaving the workforce. Many at MIT still regarded women's presence as provisional; the post-WWII baby boom and national cult of white middle-class homemaking added ammunition for those who wished to revert to conventional gender norms. But alternate voices advocated for the value of coeducation. For all the talk that engineering was contrary to women's nature, MIT's admissions office had in fact artificially kept down the number of women accepted, evaluating them more selectively than men. In a typical year, MIT rejected at least four qualified women solely because it had no place to house them. In 1960, alumna Katherine McCormick pledged $1.5 million to build MIT's first on-campus women's dorm. The resulting publicity splash made many people aware for the first time that MIT was coed, and in 1964, the number of women applying jumped by 50 percent. Throughout the late 1960s and early 1970s, the few women professors at MIT—Emily Wick, Mildred Dresselhaus, Vera Kistiakowsky, and Sheila Widnall—promoted the cause of women's engineering education. Female students campaigned to change the MIT environment, broaching the subject of sexual harassment and the many negative comments that women encountered in classrooms and laboratories. Activists kept raising the issue of numbers, worried that female engineering students would never win respect if they remained below a critical mass. Between 1963 and 1973, the number of women enrolled at MIT tripled.

Each of these three schools serves as a unique lens that has been shaped by its institutional history and character, by geographical context and era, and by the political and

personal inclinations of key figures in college leadership, including students, alumni, professors, administrators, and the general public. Georgia Tech's debate over coeducation reflected, among other factors, the clash between Southern traditions and a pressure for modernization to accommodate women and racial minorities in the nascent civil rights movement. Caltech's consideration of female undergraduate admission occurred a decade and a half later when southern California was modeling a hedonistic lifestyle and the student movement of the 1960s promoted youthful sexual liberalization and challenges to authority. At MIT, internal arguments about whether to end or extend coeducation peaked during America's cold war race to keep ahead of the Soviet Union in science and technology, adding international political weight to the question of whether trying to train more women in engineering was a logical advance or an inappropriate waste of time.

At the same time, across these campuses in different years, discussions of coeducation at each school raised overlapping questions, comments, and concerns about the issue of women as engineers. Georgia Tech, Caltech, and MIT all possessed ingrained norms that equated engineering study and technical knowledge with masculinity. Subscribing to theories of gender dichotomy stretching back to the ancient Greeks, popular campus assumptions linked men with rationality, action, and strength and women with emotion, passivity, and flightiness. In a century of technological advances from the Wright brothers to jet aircraft and intercontinental missiles, male engineering students symbolized intellectual and, by extension, national progress. Defined by their absence from that world, women represented, at best, future wives whose appealing femininity and steadying home influence would help engineer husbands succeed and, at worst, temptresses whose frivolity risked distracting good, sound men. The traditional engineering campus actively resisted female influence and indoctrinated men through an atmosphere charged with fraternity, empowering them by marginalizing women. The annual St. Patrick's ball and other social functions relegated women to the function of dates and prizes to be paraded and admired. In the engineering school, women otherwise were most visible in their capacities as secretaries, low-level research assistants, administrators in female niches such as the library, and professors' helpmates.

To skeptics, coeducation threatened to upset a smoothly functioning status quo. For them, a feminine presence would destroy the cohesion that was created through male bonding and destabilize effective teaching. All three schools raised scholastic pressure to a mandatory virtue, nurturing a conviction that professors could mold students into the best engineers and scientists only by driving them to the limits of endurance. Graduates took a virile, professional pride in having survived that trial by fire. Some male students,

alumni, faculty, and administrators feared that adding female students would dilute that classroom intensity and rite of passage, compromising their institution's reputation. The ongoing use of language painting women as invaders underlined the masculine desire to retain ownership of engineering life.

As Georgia Tech and Caltech became coeducational and as MIT moved toward admitting more women, such assumptions intensified gender tensions surrounding the engineering campus. Throughout the 1950s and into the 1960s and beyond, men (and often other women) continued to regard female engineering students as curiosities. Ironically, even as many of the first women at these three schools were swamped by unabashed stares or unwanted attention from their male counterparts and inquiries from the media, they appeared to be a virtual footnote within the official institution. The default student in admissions bulletins and campus rhetoric remained male. It took uncomfortably long for administrators to figure out how to provide women with adviser support or even decent athletic facilities.

Feeling like second-class citizens on campus, the first generations of entering women felt perpetually on trial, under scrutiny to prove not only their individual ability but also the worth of their entire sex. In a commonality across all three schools and elsewhere, female students found that many Americans often refused to believe that women could be serious about pursuing technical work. Male classmates and casual acquaintances suggested that women enrolled in engineering simply to "catch a husband." Especially during the 1950s, such assumptions were no coincidence, given that the nationwide dropout rate for female students overall was relatively high, as was the rate of women's marriage either during or immediately after attending college. In fact, a number of women in that era admitted that one of their major goals in their higher education was to obtain a "Mrs. degree." But female engineering students who had demonstrated their brainpower and determination found such repeated questioning infuriatingly patronizing.

Although many faculty members proved to be supportive of female students, others displayed either hostility or an embarrassing favoritism. Even a professor's casual comments in class could reveal an awkward sexism. Certain male classmates simply were not ready to respect women in engineering as intellectual equals, future professional colleagues, or even normal fellow students. Instead, a good part of campus culture still reduced women to sexual objects who were evaluated on hair and eye color, body shape, and girlfriend potential. Official college engineering magazines and advertising by the country's largest advanced-technology corporations portrayed women as pinups in tight sweaters or swimsuits and ran raunchy cartoons that glamorized men's pursuit

of sexual conquests. Especially in years when gender ratios in enrollment were particularly skewed, female students reported being bombarded with romantic approaches. In a youth-dominated environment that often seemed to facilitate relaxation of sexual mores, some women felt that men perceived them almost as prizes to be distributed.

Ironically, even as some male students made female classmates the targets of sometimes oppressive social and sexual pressures, popular lore at MIT, Caltech, and Georgia Tech also commonly disparaged the entire category of female engineers as ugly and undesirable. Some women ignored, challenged, or laughed off such slurs, but the often vicious portrayals could reinforce the worst fears of vulnerable young women. Those negative images both reflected and perpetuated the impression that normal women did not want to pursue technical subjects, a message that often was blamed for discouraging girls. Stereotypes thus denigrated female engineering students on both intellectual and personal levels, calling into question their worth both as females and as engineers.

Despite such obstacles, some of the first women at Georgia Tech, Caltech, and MIT and in engineering studies elsewhere survived and even thrived. Those students were fortunate or resourceful enough to find or establish a comfortable atmosphere that helped build their self-confidence, often with encouragement from male peers and professors, female friends, and outside backers such as the Society of Women Engineers (SWE). For the women who did graduate, often at or near the top of their engineering classes, academic success and personal fulfillment combined to make education in a male-oriented institution not only bearable but often richly pleasurable. Some insisted (at least publicly) that they themselves had never experienced any discrimination. Others took pride that their persistence ultimately overcame the doubters and won them acceptance among faculty and classmates. In negotiating survival strategies, some female engineering students embraced a self-identity as "one of the guys," studying alongside men, often amid friendly teasing. Other women (or sometimes the same women at other times) deliberately displayed their femininity, proud of being interested in fashion, skilled in the kitchen, and enjoying hobbies such as sewing. Virtually no woman in engineering studies could completely ignore her gender. Even those who fared well had to consider, reconsider, and reposition their attitudes toward femininity, other women, male classmates, teachers, and potential employers.

For other female students, an initial choice of engineering enrollment ultimately entailed more misery than reward. Without comprehensive statistics, it is impossible to tabulate definitively the number of women who transferred out of engineering, switched to other colleges, or dropped out of school. For some, the move may have been a positive step in their ongoing maturing as college students as they discovered

other paths that were more personally appealing to them than engineering. But for others, the loneliness and uncertainty that faced a woman who was trying to break into a man's field multiplied the stresses caused by difficult classes and the coldness (sometimes outright antagonism and harassment) from some male classmates and teachers. Issues surrounding gender and engineering complicated the already disorienting process of leaving home to start college, with its mixture of anxieties and possibilities. Their decisions were not made in a vacuum. Personal campus experiences were embedded within the wider realities that faced women in engineering, which inevitably influenced individual academic outcomes.

As the final chapter here details, the American campus environment gradually but significantly evolved, especially in the late 1960s and 1970s, as a result of developments inside engineering programs and in society as a whole (including the rise of second-wave feminism, civil rights legislation, and decisions by national institutions to promote the success of women in science). Female students, faculty members, and other activists, in alliance with male advocates of liberalization, mobilized to pressure educators for change. For them, numbers made a difference. Their campaigns stressed the need for engineering colleges to work on attracting more women to attain a critical mass. After the female presence rose to a tipping point, those women gained power to support each other, both informally and through organizations such as SWE chapters.

For political and personal reasons, a number of women in engineering remained reluctant to identify themselves as feminists. Yet the feminist movement provided essential ideological, philosophical, and community support for a vital core of campus women who gained the language, voice, and courage to protest against sexist comments and demand an end to sexual harassment in classrooms, labs, and dorms. Those leaders insisted on holding schools accountable for breaking down institutional barriers and making visible changes for women in engineering programs.

College students themselves, along with established professionals, created other subversive initiatives aimed at encouraging young women to pursue technical interests. In the process, they expanded the discussion of how teachers, peers, the media, and the general culture affected the socialization of girls, leading them to internalize both positive and negative ideas about their life options. SWE and smaller groups of female engineers tried to reshape the messages projecting what academic, career, and personal directions were standard or unusual for women.

The Society of Women Engineers provided avenues for women to mobilize and provide each other with professional, social, psychological, and financial assistance. Women studying engineering at individual schools constructed their own interest groups and

support strategies, adding up to some tangible improvement in the gendered conditions of engineering study. Starting in the 1960s, activists organized dozens of conferences, open houses, and other public events across the country to celebrate and advance women's achievements in engineering. Through networking, panel discussions, and publications, established professionals sought to leverage individual successes to build solid mechanisms that they hoped would ease the path for women coming along later. In consulting mentors and role models, younger women sought advice, including answers to persistent concerns about juggling career and family. Female engineering students during this era remained optimistic that excellence would win out and that talented women generally would not face any crippling discrimination in securing good jobs.

For all their value in providing professional advice, psychological reinforcement, scholarships, and other tangible assistance to young women in engineering, SWE and campus-based organizations could not totally transform the gender environment of the field overnight. Even the most supportive faculty and administrators could not wave a magic wand and bring female enrollment in technical majors up to 50 percent, nor could they guarantee a campus environment that was perfectly free of all gender stresses. The continued effort to reshape the national picture of women in engineering is the subject of the final chapter here. In retrospect, the postwar decades brought an often-impressively rapid increase in female engineering students, especially in certain majors and at specific institutions. But more recently, some observers have worried that women's representation in the discipline has hit a plateau, with enrollment leveling off or even declining. They interpret such trends as disturbing evidence that efforts to encourage women to consider nontraditional fields have stalled and that fundamental problems of gender inequity have lingered.

As feminist activists of the 1960s and 1970s pointed out, advocates can take many steps to improve women's college-level experiences in engineering and thus improve their retention rates and subsequent success, but intervention at the level of higher education often comes too late. Over recent decades, many elementary schools, middle schools, high schools, and communities have made heroic efforts, often working with the Girl Scouts and many other groups to nurture girls' interests in engineering and science. Through gender-neutral or girl-positive language and images, reformers hoped to meet the broad challenge of reshaping stubbornly ingrained notions of gender appropriateness and the cultural meaning of engineering.

By the start of the twenty-first century, almost all schools that offer serious programs in engineering had formally incorporated women into those disciplines and indeed initiated special efforts to recruit and support female students. As at Georgia Tech, Caltech,

MIT, and other schools in previous decades, female students' individual experiences after enrollment can vary dramatically. Some current women students take for granted that their years studying engineering have not included any major intellectual and social hassles, while others in different (or even the same) programs relate ongoing stressors, including demeaning comments or disrespectful treatment. Although introductory-level engineering classes may include a relatively substantial number of women, female students still stand out by their rarity in more specialized advanced courses. The account of how women moved into once-male territory, permanently changing the social, intellectual, and institutional nature of American engineering, is a complex tale. But in the end, that rich history of ongoing evolution adds a unique perspective to discussions about ongoing issues of diversity, balance, and fairness that today face women in engineering and science.